MEASURES AGAINST FIRE DISASTER FOR LONG URBAN TUNNEL OF THE HANSHIN EXPRESSWAY YAMATOGAWA ROUTE

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ABSTRACT

The Yamatogawa Route is an expressway which is to be the south part of the new circle route around Osaka city area. Last year we studied the nature of fire disaster in road tunnels taking example of the Yamatogawa Route, investigating measures against it, and designed emergency facilities especially for emergency exits. In case of the Yamatogawa Route, we found that the distance of each emergency exit is decided from the relation between duration for safety evacuation and total evacuation time. About escape routes, we thought it is difficult to use the other directional tunnel for a escape route because of the difficulties of regulation of the other directional tunnel's traffic. Moreover, in case of the Yamatogawa Route, to go up using only emergency stairs to the out is difficult, because the road is deep from the ground. To settle this problem, we decided to use its invert space as the evacuation route, and set slides from road area to there.

In this report we will introduce these studys to deal with the fire disaster for the Yamatogawa Route.

1. INTRODUCTION

The Hanshin Expressway Company Limited, Osaka, Japan, is now constructing the Hanshin Expressway Yamatogawa Route. The Yamatogawa Route is an expressway which is to be the south part of the new circle route, and it is expected to solve the traffic congestion problem and to renew Osaka urban areas. The Yamatogawa Route will be a toll road with a length of about 9.7km connecting Sanpou area of Sakai-city with Miyake area of Matsubara-city along the Yamatogawa River (Figure 1).

The Yamatogawa Route consists of a 7.7km long tunnel, a 0.6km long sloped embankment and a 1.1km long elevated road connecting with the other elevated routes. The estimated traffic volume is about 54,000 vehicles a day. Though we are constructing other new routes, we conducted a case study about measures against the fire disaster on the Yamatogawa Route, considering these factors.

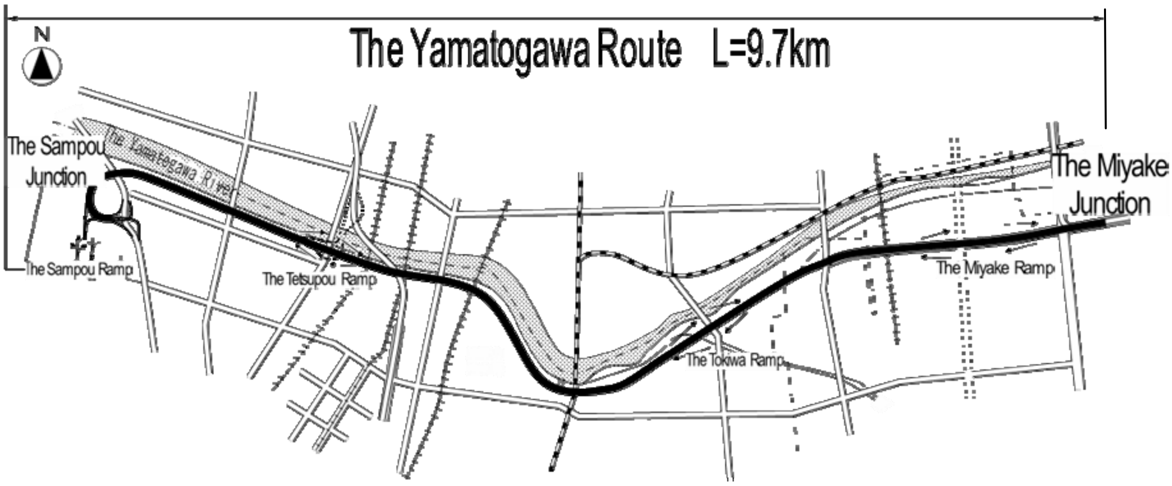


Figure 1 The Yamatogawa Route

2. THE FEATURE OF THE TUNNEL

The 7.7km long tunnel consists of one long tunnel and two middle length tunnels. The longest one is a 4.9km long shield tunnel with average depth of about 30m. So, we had to take this depth condition into consideration when we decide its evacuation route.

The construction had just begun at Oriono area of Sakai-city, last autumn.

3. SAFETY FACILITIES

On account of the length of the tunnel and the traffic volume of the Yamatogawa Route, we applied the highest AA-class of the tunnel classification system of Japan national standard into the Yamatogawa Route. From twenty some obligated emergency equipments, we show couples of safety facilities which are important for evacuation from a fire disaster at Table 1.

Table 1 Important safety facilities

No	Name of facilities	Interval of facilities
1	Flame detection system	Less than 25m and covers the entire tunnel
2	Fire extinguishers	Less than 50m
3	Closed circuit television	Less than 200m and covers the entire tunnel
4	Emergency exit	Each lay-by must have a emergency exit. And it should be located within the intervals which are decided from smoke condition.
5	Ventilation facilities	It must be arranged so as to be able to keep the air condition for both of the normal ventilation and smoke control.

We estimated that the emergency exit is the most important one of these facilities for planning

evacuation from the fire disaster. Normally, the emergency exit will be arranged at each lay-by in urban tunnel of the Hanshin Expressway, but it can be too long if we take into consideration smoke of the fire. So we investigated the condition for road users to be able to evacuate safely from a fire disaster in a limited time.

4. DESIGN FIRE

On discussing the evacuation from the fire disaster, we should define design fire at first, and then we should compose the whole evacuation method considering the effects both of somke and hot gases of the fire. It would have been better to make an experiment which examines the nature of the combustion of a real vehicle in a real tunnel, but we hadn't done it for reason of the cost of the experiment and the lack of appropriate real tunnel. Alternatively we estimated the design fire referring to the experiments carried on real vehicles in western countries. The Heat Release Rate (HRR) of a bus fire was investigated in the EUREKA EU499 FIRETUN test series[1]. HRR curve is shown in Figure 2. It was reported that the HRR increased slowly for the first 3.5 minutes after the start of the fire, and then it reached rapidly a peak of approximately 30MW. Using this HRR curve, we estimated that people can escape from the fire accident during the first 10 minutes that the fire doesn't intensify so hard.

By the way, we won't take into consideration the fire caused by highly dangerous goods, so we will go ahead with the fire caused by general burning goods.

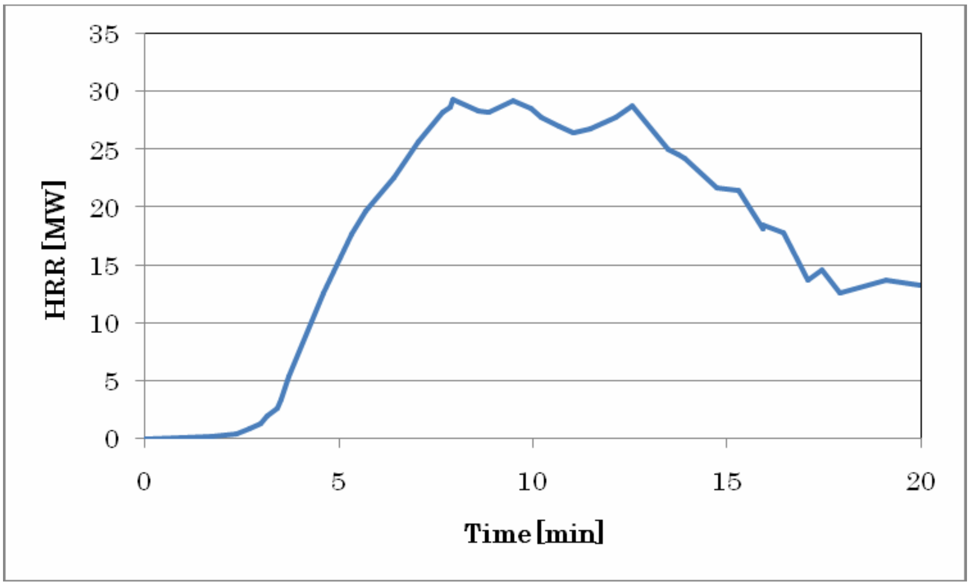


Figure 2　Heat Release Rate curve

5. THE EVACUATION TIME

At first, we will handle free flow traffic state. Because the Yamatogawa Route has longitudinal ventilation system, we can stable the air flow forward condition. In this state, people who are over the

fire accident can escape easily by driving naturally forward, and people who are front of the fire accident can escape safely if only the smoke doesn't move backward. Therefore, the self-evacuation condition can be kept if we can control the longitudinal ventilation so as not to occur the back layering upstream of the smoke.

Next, we will scrutinize the fire accident in a traffic jam. In this state, we cannot flow the air longitudinal because of the existence of road users over the fire accident. So, the emergency exit should be located so that people can run into it during a certain duration of safety evacuation. That's why we investigated the interval from the start of the fire accident to the arrival of people at emergency exit. Figure 3 is the flow chart which explains these incidents from the start of the fire to the arrival of people at the emergency exits. From now on, we investigate each durations of the parts of Figure 3.

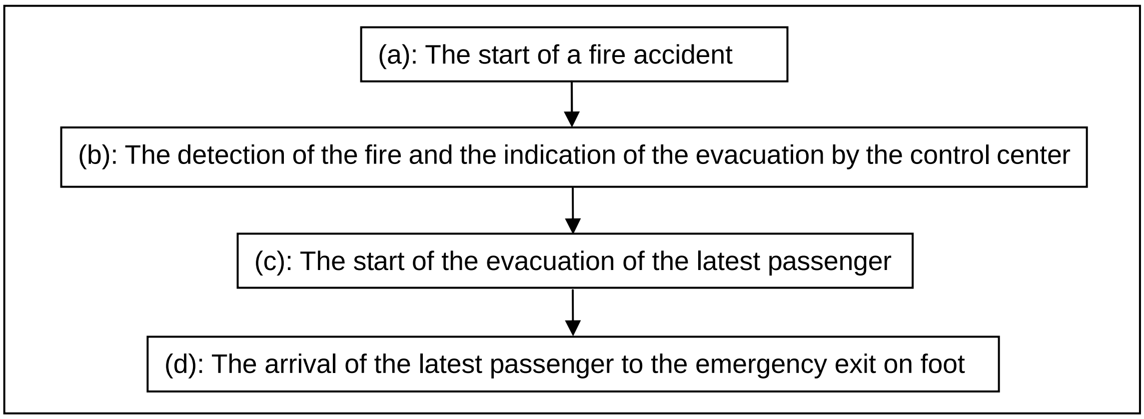


Figure 3 The flow chart which explains the incidents about the evacuation

5-1. The interval from (a) to (b)

For detecting the fire and indicating evacuation, we are planning that the Yamatogawa Route will be manned on a 24-hour basis. So, rapid fire detection will be possible by CCTV or communication with patrol cars, or other provisions. Considering these conditions, we decided the interval from (a) to (b) as 2 minutes for the Yamatogawa Route.

5-2. The interval from (b) to (c)

As for the interval from the indication to the beginning of self-evacuation, we investigated the time need for descending from a full size bus.

We must decide the interval through which all the passengers on a bus can leave, considering the condition on that how many people can walk through a certain width of a threshold within a certain time, because many people must pass through one exit to escape from a bus. Estimated time for the passengers on a bus to leave it is concluded as follows, considering the width of the exit of a bus and the number of people to escape. We rounded up the figure to 2 minutes.

A: Number of people that can walk through an exit with 1m width in a second

: 0.65 person/meter/second

B: Width of the exit of a bus : 1.1m~1.5m

C: Number of people using a bus : 50 persons

D: Calculated time for the passengers on a bus to leave it :

D = C / (A × B)= 69.9second ~ 51.28second

→ 2 minutes (rounded up)

5-3. The interval from (c) to (d)

We estimated the walking speed at 1m/s considering handicapped people. The necessary time for evacuation differs in the distance from the vehicle to the exit. This distance becomes the longest in the case where the passengers must escape from an exit where the fire accident had occurred to the next one. In this case, the necessary time to walk is as follows.

Ｌ(m)÷1m/s＝Ｌ(s)＝Ｌ／60 (min)

, where L (m) is the distance between two exits.

5-4. The total evacuation time

Now, the necessary time from (a), the start of a fire accident, to (d), the arrival to the emergency exit on foot becomes the summation of these intervals, as following.

2＋2＋Ｌ／60 (min)

6. THE DURATION FOR SAFETY EVACUATION

When we consider the duration for safety ecacuation, we should take the effects both of somke and hot gases.

About hot gases, the evacuation must be done in the first 10 minutes in which the fire does not intensify as we mentioned above.

As for the smoke, the time for safety evacuation depends on the geometric nature of the tunnel. A literature [2] says, the smoke, soars upward to the ceiling, spreads back and forth beneath the ceiling maintaining its own stratified shape in some period if there is no air flow and no gradient of the ceiling. And it descends downward if more the distance from the fire and/or the past time. On the other hand, the smoke soared to the higher place along the ceiling, under the influence of the gradient of the ceiling, called “chimney effect”, descends earlier and nearer due to the disturbance of the smoke. We investigated the relation between the time which the smoke descends downward and the distance from the fire accident using 3-Dimensional analysis on a second basis. As we report it in another paper in this 13th REAAA Conference (“An examination on smoke control by means of numerical simulation in a long urban tunnel (the Yamatogawa tunnel)”), we only quote its conclusions here. When we consider

both fo the 10 minutes decided by hot gases and the time decided by the relationship between the smoke and the longitudinal gradient, Table 2 shows the past time and the distance where people who had started to walk just 4 minutes after the fire accident would be captured by smoke and hot gases.

Table 2 The relation between the past time and the accessible distance

No	Longitudinal gradient	Past time	Distance
1	0.3%	More than 10 minutes	More than 300m
2	2.0%	8.6 minutes	280m
3	3.0%	7.3 minutes	200m

7. Criterion for safety evacuation

The necessary condition for the passengers to be able to evacuate safely from the fire accident is as follows. :

At each interval of emeregency exit,

The duration for safety evacuation (Table 2)

≧ The total evacuation time (2＋2＋L／60 (min))

We deployed emergency exit under this condition. Figure 4 shows the results.

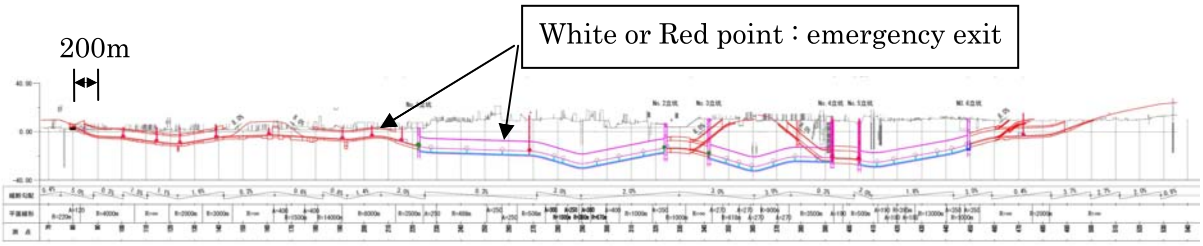


Figure 4 The location of the emergency exits

8. EVACUATION FROM THE SAFETY AREA TO THE OPEN

By means of the arrangements of the emergency exits at those locations we mentioned above, we estimate that the safety of the passengers can be held in a certain stable level, but some dangerous elements remain here until passengers could reach the out. Now, we are going to investigate the pass which leads passengers from emergency exit to the out.

We can pick up couples of methods which connect the emergency exit with the outer area, each contains both of plus and minus factors, as shown Table 3.

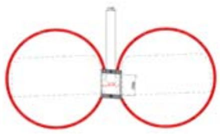
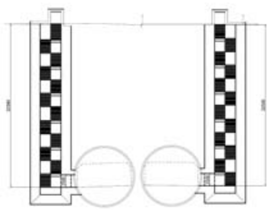
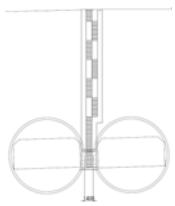
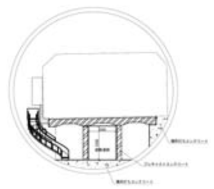
If emergency stairs were located at each emergency exit, it is not easy for all the passengers to move vertically using only stairs. Additionally, it is easily assumed the risk that the emergency stairs doesn't work well by the jam-packed people caused of stops of weak persons. The vertically deep road, like the Yamatogawa Route, will have a greater tendency on this character. Besides, it costs match to

set stairs at each emergency exit.

If the passengers escape to the other directional tunnel by using the transversal tunnel connecting the each directional tunnel, the safety against the danger of the traffic of the other tunnel must be secured by regulating the traffic until the evacuees reach the emergency exit. But it is not easy to regulate the traffic of the other directional tunnel in a certain short time.

As a result, we adopted the escape route that consists of slopes located at each emergency exit and a safety escape route connecting slopes with the emergency stairs. The evacuees slide down the slopes to the safety escape route, walk up to certain height along it, and escape to the out by using emergency stairs. Figure 5 shows the details of the slope and the safety escape route. The fire brigades can also use this emergency stairs for rescue. By these facilities, we estimate that the safety of evacuation was secured.

Table 3 Methods which connect the emergency exit with the outer area

No		Summaries of facilities	Plus+/Minus- factor
1		Transversal tunnel, located in the gap of the two directional tunnels, connect each directional tunnel.	+ : no need of independent escape route - : difficulties of regulation of the other directional tunnel's traffic
2		Emergency stairs located at each exits.	+ : no need of regulation of the other directional tunnel - : cost much, need lands, it is not easy to move vertically using only stairs.
3		Emergency stairs, located in the gap, utilized for each directional tunnel	+ : no need of further land acquisition - : cost much, it is not easy to move vertically using only stairs.
4		Slope, located at each exit, and safety area connecting with the open	+ : not cost much, no need of further land acquisition - : difficulties of guidance

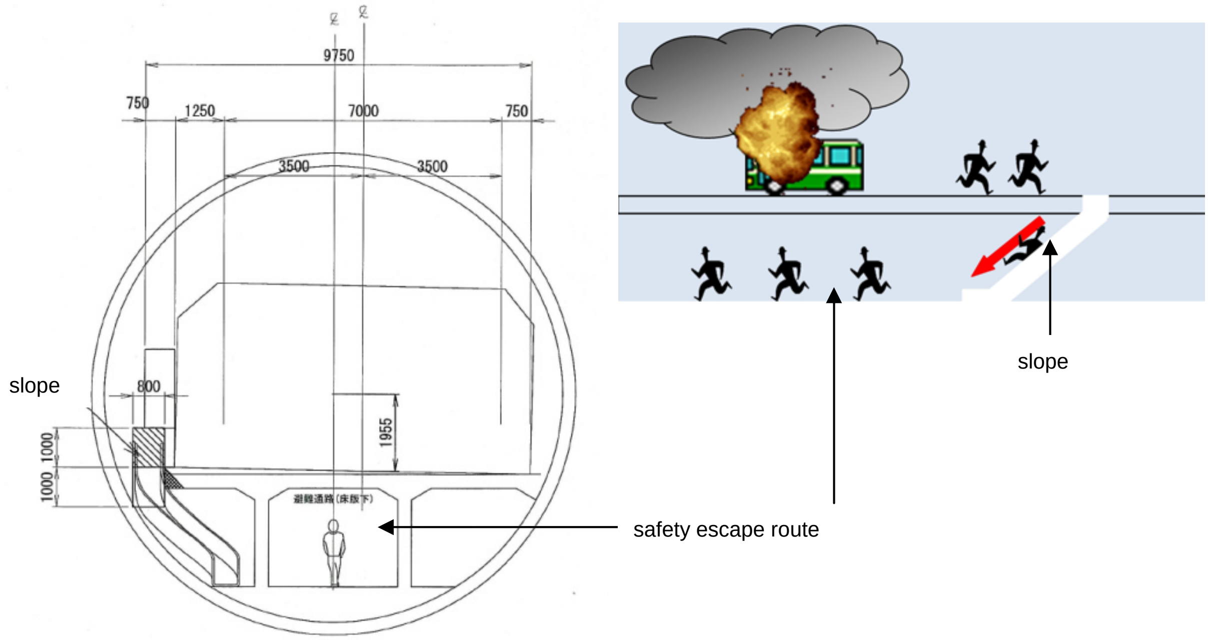


Figure 5 The details of the slope and the safety escape route

8. CONCLUSION

As we mentioned above, we had conducted a case study about measures against the fire disaster on the Yamatogawa Route which will be the longest and have the biggest traffic volume among couples of new highway routes which we are going to open in these few years.

In the case of the Yamatogawa Route, there were some premises as follows.

- The longitudinal gradient varies from 0.3% to 3.0%.
- The depth of the road is about 30m from the ground level.
- It is possible to make a safety escape route under the road using advantages of shield tunnel.

On considering these conditions, we could compose emergency facilities of the Yamatogawa Route, as follows.

(a) We could arrange the emergency exits so that the evacuees can reach them in the duration of the safety evacuation's condition.

(b) The evacuees slide down the slopes located at each emergency exits to the safety escape route under the traffic space, walk up to certain height along it, and escape to the out by using emergency stairs

Now, we could nearly settle the location and design of the emergency facilities. So from now on, we are going to investigate structural details of these facilities we mentioned above and operational procedure of them.

ACKNOWLEDGMENT

We will express our great gratitude to the members of the technical committee “Committee of the Safety against the Tunnel disaster and Traffic” (Chairman: Yasunori-Iida, honorary professor of Kyoto-University).

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